# The Stratigraphic Palynology of Bores Along the Darling River, Downstream From Bourke, New South Wales.

HELENE A. MARTIN

School of Biological Science, University of N.S.W., Sydney 2052.

The palaeovalley of the Darling River has been interpreted as a series of small en echelon basins or shallow grabens, with Tertiary fill overlying the Early Cretaceous basement. A saline aquifer is trapped at some depth and where deflected upwards, discharges into the river in places, such as near Glen Villa, downstream from Bourke. The palynology shows that the base of the Tertiary sediments is late Eocene at Tilpa and late Oligocene–early Miocene from Louth to 'Jandra'. The basement is earliest Early Cretaceous and may be of marine or freshwater origin.

The vegetation was probably a mixture of rainforest and Casuariaceae forests through the Tertiary, indicative of a much higher precipitation than that of today. In the late Pliocene-Pleistocene the forests had disappeared and the vegetation had become open, indicating a reduced precipitation, but it was considerably higher than that of today. The palaeoenvironments recorded by the Tertiary sediments suggest freshwater deposition. The high salinities have developed subsequent to the early Pleistocene.

## INTRODUCTION

When Charles Sturt explored the Darling River, he discovered unpotable saline water, downstream of Bourke. In certain places, saline water is discharged into the river from a thick, saline aquifer in the Tertiary sediments that fill the ancient valley. The Darling River (Fig 1) follows an ancient fracture zone of the Darling River Lineament (Mount 1992). The Tertiary sediments southwest of Bourke fill a series of discontinuous shallow basins that are potentially favourable for pollen preservation. To be preserved, pollen must be buried sufficiently to escape the destructive effects of a fluctuating watertable. Outside of the Murray Basin, with its active though slight tectonism (Brown 1989), where Tertiary pollen assemblages are commonly encountered (Martin 1984a, 1984b, 1993, Macphail and Truswell 1989, 1993), few such Tertiary assemblages have been found west of the Western Slopes of New South Wales.

Tertiary palynofloras in these inland arid regions are of special interest for they assist in the understanding of the evolution of the arid vegetation. They may also provide some evidence of the development of saline groundwaters as the microplankton content may indicate the water quality at the time of deposition. This paper presents the palynology of the Tertiary sediments of the Darling River palaeovalley and the underlying Cretaceous basement, where encountered.

## MATERIALS AND METHODS

Samples used in this study are cuttings as core samples were not available. The possibility of contamination is greater with cuttings, both from carry down with the circulating
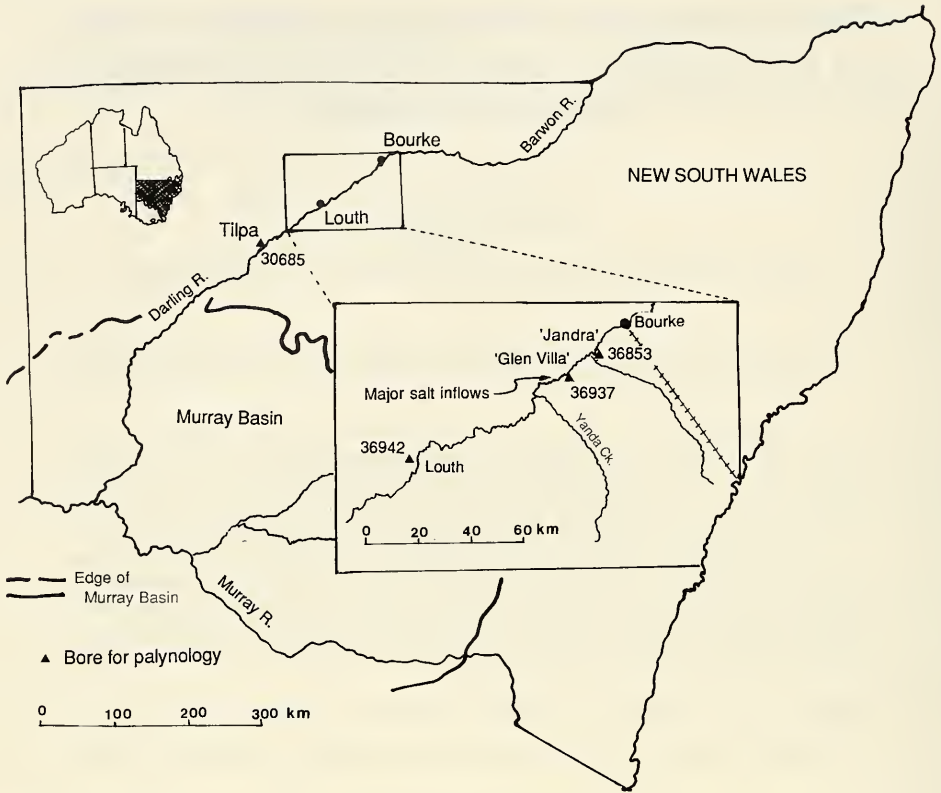
*Figure 1.* Locality map.

mud and from cavings, but with proper drilling and sampling procedures, relatively uncont-aminated samples may be obtained. For investigative drilling, the mud is circulated until it is clean of the coarse fraction and this practice greatly reduces contamination. Contamination may be assessed from bores that penetrate both the Tertiary sediments and the Cretaceous basement, where Tertiary contamination is either absent or minimal in the Cretaceous assemblages, thus increasing confidence in the reliability of the samples. Barren samples may occur anywhere in the sequence and these would not be possible with appreciable contamination. While the possibility of contamination can not be ruled out completely, cuttings produce consistent patterns, repeated in bore after bore, and this con-sistency would not be possible with appreciable contamination. There is thus reasonable confidence that these samples produce reliable results (Martin 1984c).

Preparation techniques used hydrochloric and hydrofluoric acids to remove the mineral material, controlled oxidation with cold Schultz solution, and potassium carbon-ate to clear the residues which were then mounted in glycerine jelly.

## GEOLOGY

The Darling River Lineament (Mount 1992) defines the junction between outcrops of the Lachlan Fold Belt to the southeast and the Great Artesian Basin to the north. The palaeovalley of the Darling River was formed partly by the downwarping and block col-

lapse of an older surface, possibly a peneplain, and partly by concurrent erosional incision. The basins forming the palaeovalley of the Darling River have been interpreted as a chain of en echelon grabens, to approximately 150 m depth, strung out along the Darling River Lineament. These grabens have been formed in response to alternating sinstral, but predominantly dextral strike-slip movement, probably in the upper mantle, along the Darling River Lineament (Mount 1992). The Cainozoic valley deposits form a linear belt along the lineament.

Two main units are recognised in the Tertiary valley fills:

(1) An upper grey, silty clay of the modern floodplain, approximately 7–10 m thick, which is probably equivalent to the Shepparton Formation in the Murray Basin, of Pliocene-Quaternary age. In places, the river has cut through this unit.

(2) A main aquifer zone below the 'Shepparton Formation' equivalent. It consists of an upper sand layer, two main cycles of coarse sand and fine gravels in the middle and towards the base, carbonaceous muds containing wood fragments. This unit is thought to be equivalent to the upper part of the Palaeogene Renmark Group of the Murray Basin (Mount 1992) but this study shows that it is mid-late Tertiary and possibly early Pleistocene in age.

Individual bores showed minor grey clay lenses through the second unit. The grey and carbonaceous clays are best for palynology, but pollen recovery has been sporadic. The lithologic logs of the bores are shown in Table 1.

TABLE 1

Lithologic logs. The ages given for the palynological samples are from this study.

| DEPTH (M) | DESCRIPTION |
| --- | --- |
| **Bore 30685** | **Tilpa** |
| 0–11.3 | Grey sandy clay |
| 11.3–21.6 | Sandrock |
| 12.6–26.2 | Grey clay |
| 26.2–37.5 | Grey clay and sandrock<br>Sample for palynology, 30.5 m, barren |
| 37.5–59.4 | Grey clay |
| 59.4–70.1 | Grey sandy clay |
| 70.1–212.7 | Dark green shale with hard bands. Sample for palynology, 72.6 m, late Eocene<br>Sample for palynology, 91.4 m, Early Cretaceous |
| 212.7–214.8 | Dark green shade<br>Sample for palynology, 213.4 m, Early Cretaceous |
| **Bore 36942** | **Louth** |
| 0–9 | Yellow grey, grey brown and light grey clay and silty clay |
| 9–15 | Grey to yellow quartz sand with gravel at the base |
| 15–22 | Light to mid grey clay with wood at the base<br>Sample for palynology, 20–22 m, late Pliocene–early Pleistocene |
| 22–24 | Quartz sand with some fine gravel |
| 24–30 | Grey clay, silty clay and gravelly clay |
| 30–32 | Quartz sand with some clay and wood |

| | |
|---|---|
| 32–41 | Light grey clay with minor mottles, laminations and silty bands |
| 41–46 | Quartz sand with minor yellow silt |
| 46–47 | Quartz gravel and yellow clay |
| 47–48 | Silcrete, fine gravel and siliceous sandstone |
| 48–59 | Mid to dark grey clay with minor carbonaceous bands<br>2 samples for palynology, 49–50 m and 50–51 m, Early Cretaceous |
| 59–60 | Fine grained quartzose sandstone with minor mid to dark grey siltstones<br>Sample for palynology, 59.2 m, Early Cretaceous |
| **Bore 36937** | **Glen Villa** |
| 0–12 | Pale grey and pale brown clay and silt, some mottling |
| 12–13 | White kaolinitic sand |
| 13–49 | Sand in a pale grey to white and pale yellow to yellow clay matrix |
| 49–56 | Gravelly coarse sand, quartzitic |
| 56–57 | Lignitic dark brown humus with peaty wood chips.<br>Sample for palynology, 56–57 m, late Oligocene–early Miocene |
| 57–61 | Sand, pale grey |
| 61–69 | Sand and gravel, pale grey |
| **Bore 36853** | **'Jandra'** |
| 0–10 | Grey brown and yellow brown clay |
| 10–17 | Fine sand, light yellow brown |
| 17–19 | Sandy clay, blue green and light grey |
| 19–21 | Quartz gravel with light grey clay |
| 21–27 | Grey clay<br>Sample for palynology, 21–23 m, late Pliocene–early Pleistocene |
| 27–35 | Light yellow brown clay |
| 35–47 | Sand with light grey and yellow brown clay |
| 47–55 | Dark grey clay with some sand |
| 55–71 | Sand, carbonaceous in places<br>Sample for palynology, 61–63 m, ?mid–late Miocene |
| 71–139 | Quartz gravel with minor sand layers, light grey |
| 147 | Shale, dark grey to black<br>Sample for palynology, 147 m, Early Cretaceous |
| 147.4 | Shale and sandstone |

Salt inflows are located in the bed of the river and are controlled by the geological structure. A saline aquifer is trapped beneath the 'Shepparton' clays and a ridge of bedrock at 'Jandra' functions as a subsurface 'dam' and impedes the southwesterly movement of the groundwater. The work of Mount (1992) has developed a model for saline groundwater inflows to the River in terms of geological and structural control of the saline aquifer, especially the regional lineaments and the en echelon graben geometry of the Tertiary basins along the Darling River (Mount 1992).

## STRATIGRAPHIC PALYNOLOGY

### Early Cretaceous

'Jandra' bore 36853 at 147 m, Louth bore 36942 at 49–59 m and Tilpa bore 30685 at 91–213 m (Table 2)

TABLE 2

Cretaceous species identified. References: (1) Dettmann 1963, (2) Helby et al. 1987, (3) Backhouse 1978, (4) Lentin and Williams 1989, (5) Morgan 1980, (6) Playford and Dettmann 1965.

| Locality | Jandra | Louth | | | Tilpa | |
|---|---|---|---|---|---|---|
| Bore (DWR) | 36853 | 36942 | | | 30685 | |
| DEPTH m | 147 | 49–50 | 50–51 | 59.2 | 91.4 | 213.4 |
| **SPORES** | | | | | | |
| *Aequitriradites spinulosus* 1 | | | + | | | + |
| A. *verrucosus* 1 | | | + | | | |
| *Baculatisporites comaumensis* 1 | C | + | + | + | + | + |
| *Ceratosporites equalis* 1 | + | + | + | + | + | + |
| *Cicatricosisporites australiensis* 1 | | | | | | + |
| C. *ludbrookii* 1 | | | | + | | |
| *Coptospora striata* 1 | | | | | | + |
| *Couperisporites tabulatus* 1 | | | | | | + |
| *Crybejosporites stylosus* 1 | + | + | | | + | |
| *Cyathidites australis* 1 | + | + | C | + | + | + |
| C. *concavus* 1 | | + | | | | |
| C. *minor* 1 | + | + | | | + | + |
| *Cyclosporites hughesii* 1 | + | | | | | |
| *Dictyophyllidites pectinataefornis* 1 | | | + | | | |
| *Dictyotsporites complexis* 1 | + | | | + | | |
| D. *speciosus* 1 | + | | | | | |
| *Foraminisporis dailyi* 1 | + | | | | | + |
| F. *wonthaggiensis* 1 | | | | | | + |
| *Foveosporites canalis* 1 | | | | + | | |
| F. *parviretus* 1 | | + | | | | |
| *Gleicheniidites circinidites* 1 | + | C | + | | + | + |
| *Ischyosporites punctatus* 1 | + | | | | | |
| *Klukisporites scaberis* 1 | | + | | | | |
| *Krauselisporites linearis* 1 | + | | | | | |
| *Leptolepidites verrucatus* 1 | | + | | + | + | + |
| *Lycopodiacidites asperatus* 1 | + | | | | | |
| *Murospora florida* 1 | | | | | | + |
| *Neoraistrickia truncatus* 1 | + | + | + | + | | + |
| *Osmundacidites wellmanii* 1 | + | + | + | C | + | + |
| *Pilosisporites notensis* 1 | + | | | | + | + |
| P. *parvispinosus* 1 | | | | | | + |

| STAGE | SPORES AND POLLEN | | DINOFLAGELLATES | |
|---|---|---|---|---|
| | ZONES | RANGES | RANGES | ZONES |
| CRETACEOUS — ALBIAN | Coptospora paradoxa | | | Muderonga Superzone |
| CRETACEOUS — ALBIAN | Crybelosporites stylosus | | | Muderonga Superzone |
| CRETACEOUS — APTIAN | Cyclosporites hughesii | | | Muderonga Superzone |
| CRETACEOUS — BARREMIAN | Foraminisporis wonthaggiensis | | | Muderonga Superzone |
| CRETACEOUS — HAUTERIVIAN | Foraminisporis wonthaggiensis | | | Muderonga Superzone |
| CRETACEOUS — VALANGINIAN | Foraminisporis wonthaggiensis | | | Muderonga Superzone |
| CRETACEOUS — BERRIASIAN | Cicatricosisporites australiensis | | | |
| JURASSIC — TITHONIAN | Retitriletes watherooensis | | | |

Range species (spores and pollen): Retitriletes watherooensis, Aequitriradites spinulosus, Pilosisporites notensis, Cicatricosisporites australiensis, Cicatricosisporites ludbrookii, Crybelosporites stylosus, Retitriletes facetus, Foraminisporis wonthaggiensis, Cyclosporites hughesii.

Range species (dinoflagellates): Cribroperidinium edwardsii, Nummus monoculatus, Spiniferites spp.
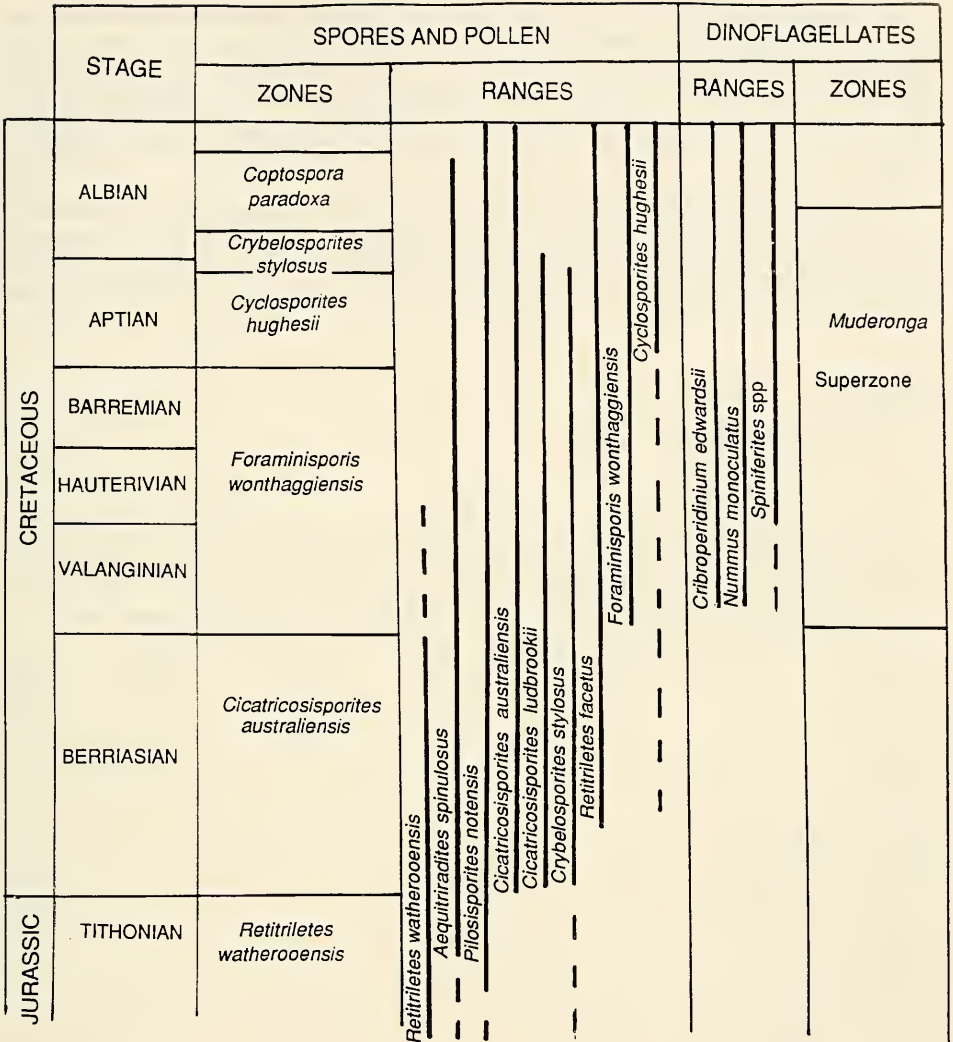
*Figure 2.* Early Cretaceous palynological zones and the ranges of diagnostic species. From Helby et al (1987) and Dettmann and Playford (1969).

The assemblages have a rich diversity of species. The gymnosperms *Microcachryidites antarcticus, Podocarpidites* spp and *Alisporites* spp are common and characteristic of the *Microcachryidites* Superzone of Berriasian into Albian age (Fig. 2). The diagnostic species *Crybelosporites stylosus* and *Cicatricosisporites ludbrookii* indicate the *Cicatricosisporites australiensis* Interval Zone of Berriasian age, in bore 36492, 49–51 m, at Louth (see Fig. 1 for bore locations). *Pilosisporites notensis* indicates the *Cyclosporites hughesii* Interval Zone of Aptian age in bore 30685, 91–213 m, at Tilpa. Bore 36853, 147 m, at 'Jandra' has the diagnostic species *Cyclosporites hughesii*, indicative of the *C. hughesii* Interval Zone (Fig. 2).

Dinoflagellates are present in two of the bores The assemblages are very limited,

but the diagnostic species *Cribroperidinium edwardsii* and *Spiniferites* spp are both present in the upper level of bore 30685, Tilpa, and their first appearance indicates the *Muderonga* Superzone (Helby et al 1987). The diversity is too limited for a more specific zone determination. Bore 36853, 'Jandra' has *Nummus monoculatus* and *Spiniferites* sp, also indicative of the *Muderonga* Superzone of Valangian-Albian age. The spore/pollen *Cyclosporites hughesii* Zone, of Aptian age, falls within the Valangian-Albian, as shown in Fig. 2.

These dinoflagellates, together with good spore/pollen assemblages, indicate deposition under marginal marine conditions. Early Cretaceous deposition was thus marginal marine during the younger Aptian *C. hughesii* Interval Zone in bore 36853 at 'Jandra' and 30685 at Tilpa, and freshwater during the older Berriasian *C. australiensis* Interval Zone in bore 36942 at Louth.

## Cainozoic

(Table 3, Fig. 3)

### TABLE 3

Tertiary spores and pollen. References: (1) Stover and Partridge 1973, (2) Dettmann 1963, (3) Martin 1973a, (4) Alley and Broadbridge 1992, (5) Martin and McMinn 1993, (6) Harris 1965, (7) Cookson and Pike 1954, (8) Pocknall and Mildenhall 1984, (9) Truswell et al. 1988, (10) Macphail and Truswell 1989, (11) Germeraad et al. 1968, (12) Martin 1973b, (13) Macphail and Truswell 1993, (14) Mildenhall and Crosbie 1979, (15) Martin 1974, (16) Cookson 1953, (17) Van Geel and van der Hammen 1978.

| Locality | Jandra | Louth | | G. Villa | Jandra | | Tilpa |
|---|---|---|---|---|---|---|---|
| Bore (DWR) | 36853 | 36942 | | 36937 | 36853 | | 30685 |
| Depth | 21–22 | 20–21 | 21–22 | 56–59 | 61–62 | 62–63 | 72.6 |
| **SPORES** | | | | | | | |
| *Baculatisporites disconformis* 1 | | | | | 1.5 | 0.7 | |
| *Ceratosporites equalis* 2 | | | | | | | 0.4 |
| *Cingulatisporites bifurcatus* 3 | | 0.7 | | | | | |
| *Cyatheacidites annulatus* 1 | | | | + | | | |
| *Cyathidites australis* 1 | | | | 0.7 | | | + |
| C. *paleospora* 4 | | | 0.7 | 0.7 | 5.9 | 3.5 | |
| *Gleicheniidites circinidites* 3 | 2 | | | | | + | |
| *Klukisporites lachlanensis* 3 | | | | 0.7 | + | 0.7 | |
| *Laevigatosporites ovatus* 3 | | | | | + | 0.7 | |
| *Polypodiaceoisporites* sp 5 | | | | 0.7 | 0.7 | 1.4 | |
| *Polypodiidites* sp 3 | | | | | 0.7 | | 0.4 |
| *Reticulatisporites cowrensis* 3/ | | 2.0 | 0.7 | | + | 0.7 | |
|     *Rugulatisporites micraulaxis* 1 | | | | | | | |
| *Reticulatisporites echinatus* 3 | | 0.7 | | | | | |
| *Rouseisporites* sp 3 | + | 4.0 | 2.7 | 1.3 | 0.7 | | |
| *Rugulatisporites trophus* 1 | | | | | 0.7 | + | |
| *Todisporites* sp 3 | | | | | 0.7 | 1.4 | |
| **GYMNOSPERMS** | | | | | | | |
| *Araucariacites australis* 3 | 4 | 0.7 | 2.0 | 1.3 | 7.3 | 5.7 | 0.9 |
| Cupressaceae 3 | | | 0.7 | 0.7 | | | 0.4 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Dacrycarpites australiensis 3 | | | | 1.3 | 2.2 | 3.6 | |
| Dilwynites granulatus 6 | | | | 0.7 | | | 0.4 |
| Lygistepollenites florinii 1 | | | | | 2.2 | | 4.0 |
| Pavisaccites catastus 1 | | | | | | | 0.4 |
| Phyllocladidites palaeogenicus 7 | | | | + | | | |
| P. mawsonii 1 | | | | | | | 0.4 |
| Podocarpidites spp 2 | | | 0.7 | 1.3 | 14.0 | 11.4 | 2.7 |
| Podosporites microsaccatus 2 | | | | | | 0.7 | |

## ANGIOSPERMS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Acaciapollenites myriosporites 8 | 1 | 4.0 | 4.0 | | | | |
| Anacolosidites acutullus 1 | | | | | | | + |
| A. sectus 1 | | | | | | | 0.4 |
| Banksieaidites arcuatus 1 | | | | | | | 0.9 |
| B. elongatus 1 | 1 | | | | | 0.7 | |
| Canthiumidites cf C. oblatus 8 | | | | | | 0.7 | |
| Chenopodipollis chenopodiaceoides 9 | 9 | 2.7 | 4.0 | 0.7 | | | |
| Convolvulaceae (panporate) | | | | + | | | |
| Corsinipollinites sp 10 | | | | 3.4 | | 0.7 | |
| Cupaneidites orthoteichus 1 | | | | 0.7 | 0.7 | 2.1 | |
| Cyperaceaepollis 9 | | 0.7 | 1.3 | 0.7 | | | |
| Dodonaea sphaerica 3 | | 0.7 | | | | | |
| Fenestites sp 11 | 3 | | | | | | |
| Graminidites monoporites 3 | 10 | 3.4 | 2.0 | | | | |
| Gyrostemonaceae 9 | | 0.7 | | | | | |
| cf Hakea | | 1.3 | 1.3 | | | | |
| Haloragacidites haloragoides 3 | 5 | 8.8 | 10.8 | | | | |
| H. harrisii 1 | 7 | 20.0 | 20.3 | 37.8 | 20.6 | 23.6 | 39.8 |
| Liliacidities sp 1 | | | | | 1.5 | | |
| Malvaceae sp 1 | | | 0.7 | | | | |
| Malvaceae sp 2 | | | 0.7 | | | | |
| Malvacearunpollis sp 9 | | | | | | 0.7 | |
| Malvacipollis sp 1 | | | | | | 0.7 | 1.8 |
| Montia sp 12 | 1 | | | | | | |
| Myriophyllum sp | | 2.0 | 4.0 | | | | |
| Myrtaceidites eucalyptoides 3 | 8 | 1.3 | 3.4 | 2.7 | 3.7 | | 0.9 |
| M. cf M. eucalyptoides | | | 4.7 | 1.3 | | | |
| M. parvus 3 | 1 | 0.7 | | 1.3 | 2.2 | 4.3 | 2.9 |
| M. verrucosus 1 | | | | | | | + |
| Myrtaceae unidentified | 1 | 6.7 | 7.4 | 8.1 | | | 0.4 |
| Nothofagidites asperus 1 | | | | 0.7 | 2.2 | 0.7 | |
| N. emarcidus 1 | | | | 9.4 | 8.8 | 17.1 | 14.5 |
| N. falcatus 1 | | | | | 1.5 | 1.4 | 0.9 |
| N. vansteenisii 1 | | | | | 0.7 | 0.7 | 2.7 |
| Nusipollenites sp (Dodonaea triquetra) 9 | | | | + | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Perfotricolpites digitatus* 11 | | | | + | | | |
| *Periporopollenites demarcatus* 1 | | | | | | | 0.9 |
| *P. vesicus* 1 | | | | | | | 0.4 |
| *Polyorificites oblatus* 3 | | | | 0.7 | | | 8.6 |
| *Polyporina granulata* 3 | | 0.7 | 0.7 | | | | |
| *Propylipollis ivanhoensis* | | | | | 0.7 | | 0.4 |
| *Proteacidites pseudomoides* 1 | | | | | 0.7 | | |
| *P. rectomarginis* 1 | | | | | | | + |
| *P. reticuloscabratus* 1 | | | | | | | 0.9 |
| *P. symphyonemoides* 1 | | | | + | 0.7 | | |
| *Proteacidites* sp | | 0.7 | | | 0.7 | 1.4 | |
| *Rhoipites ampereaformis* 13 | | | | | | 0.7 | |
| *Santalumidites cainozoicus* 1 | | | | | | | 0.4 |
| *Sapotaceoidaepollenites rotundus* 6 | | | | | | | 4.1 |
| *Simplicepollenites meridianus* 1 | | | | | | | 0.9 |
| *Sparganiaceaepollenites barungensis* 6 | | 1.2 | | 2.7 | | | |
| *S. sphericus* 14 | | | | | 2.9 | + | |
| *Tricolporites substriatus* 3/*T. paenestriatus* 1 | | | | 0.7 | 0.7 | | |
| *Tricolporopollenites endobalteus* 15 | | | | | 0.7 | 1.4 | 1.8 |
| *Tubulifloridites antipodica/simplis* 3 | 24 | 29.0 | 23.0 | | | | |
| *T. pleistocenicus* 3 | 15 | | | | | | |
| Unidentified monosulcates | | 1.3 | | | | | |
| Unidentified tricolpate/tricolporates | 7 | 4.7 | 8.8 | 19.6 | 14.6 | 11.0 | 3.6 |
| Unidentified triporates | | | | | | | 1.8 |

## ALGAE

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Botryococcus* 16 | | | | + | + | | |
| *Debarya* 17 | + | | | | | | |
| *Pediastrum* 16 | | | | + | C | | |

## SUMMARY OF MAJOR POLLEN GROUPS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Spores | 3 | 7.4 | 4.0 | 4.0 | 11.0 | 8.5 | 0.9 |
| Gymnosperms | 4 | 0.7 | 2.7 | 5.4 | 26.5 | 21.4 | 9.9 |
| Casuarinaceae | 7 | 20.0 | 20.3 | 37.8 | 20.6 | 23.6 | 39.8 |
| Myrtaceae | 8 | 8.8 | 15.5 | 13.5 | 5.9 | 4.3 | 5.0 |
| *Nothofagus* | | | | 10.1 | 13.2 | 20.0 | 18.1 |
| Asteraceae | 42 | 29.0 | 23.0 | | | | |
| Cyperaceae | | 0.7 | 1.3 | 0.7 | | | |
| Poaceae | 10 | 3.4 | 2.0 | | | | |
| Chenopodiaceae/Amaranthaceae | 9 | 2.7 | 4.0 | 0.7 | | | |

| Age | Late Pliocene–early Pleistocene | | | L. Oligo early Mio | Mid–late Miocene | | Late Eocene |
|---|---|---|---|---|---|---|---|

| EPOCH | ZONE |
|---|---|
| PLEISTOCENE | Asteraceae/Poaceae |
| PLIOCENE | *Monotocidites galeatus* |
| MIOCENE | *Triporopollenites bellus* |
| | Upper |
| OLIGOCENE | *Proteacidites tuberculatus* |
| | Middle |
| | Lower |
| | Upper *Nothofagidites asperus* |
| EOCENE | Middle *Nothofagidites asperus* |
| | Lower *Nothofagidites asperus* |

Million years: 0, 10, 20, 30, 40
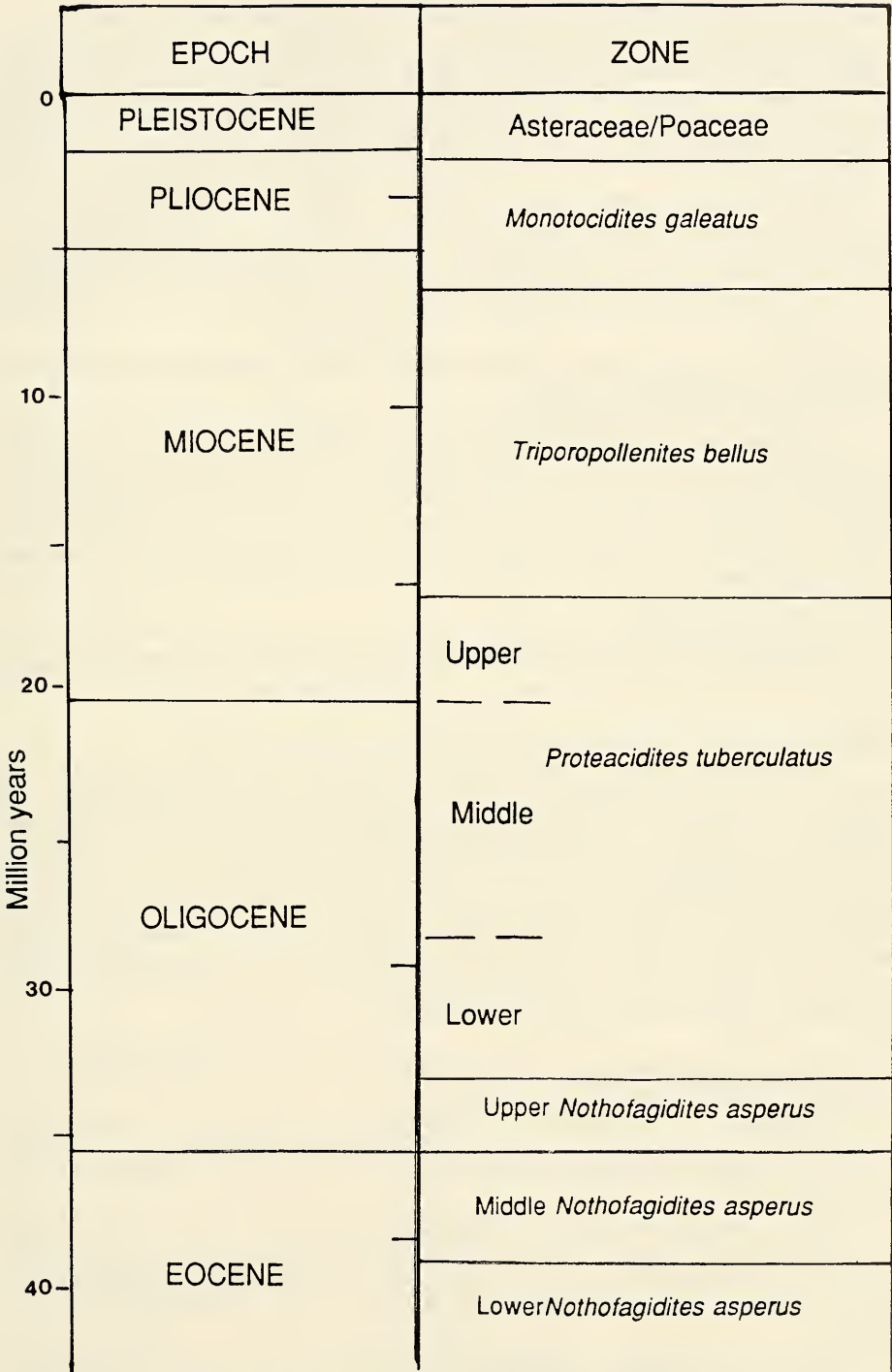
*Figure 3.* Cainozoic palynological zonation. From Stover and Partridge (1973), Macphail and Truswell (1993) and Martin (1987).

1). Late Eocene Middle *Nothofagidites asperus* Zone, Tilpa, bore 30685 at 72.6 m

The diagnostic species *Anacolosidites sectus* is restricted to the late Eocene Middle *N. asperus* Zone (Stover and Partridge 1973). *Banksieaidites arcuatus* and *Proteacidites reticulscabratus* are commonly found in the late Eocene and the ranges of *Santalumidites cainozoicus* and *Simplicepollenites meridianus* end at the top of the Middle *N. asperus* Zone. This assemblage is thus a correlative of the Middle *N. asperus* Zone (Stover and Partridge 1973, 1982).

*Haloragacidites harrisii* (Casuarinaceae) is abundant with lesser amounts of *Nothofagidites* spp and when compared with many other late Eocene assemblages, frequencies of the proteaceous pollen type (*Propylipollis* spp and *Proteacidites* spp) are unusually low. Other angiosperm pollen types are well represented, especially *Sapotaceoidaepollenites rotundus* and *Polyorificites oblatus*.

2). Late Oligocene-early Miocene, the upper part of the *Proteacidites tuberculatus* Zone, 'Glen Villa', bore 36937 at 56–59 m

The assemblage lacks diagnostic species of the latest early-mid Miocene *Triporopollenites bellus* Zone hence is placed in the underlying upper part of the *P. tuberculatus* Zone of late Oligocene-early Miocene age. *Acaciapollenites myriosporites* first appears in the early Miocene (Stover and Partridge 1973) but it is not present here, hence a late Oligocene age cannot be excluded. This pollen type, however, is rare in the early Miocene, hence its absence does not signify this assemblage is not of this age. *Cyatheacidites annlatus* and *Corsinipollenites* sp demonstrate the interval is no older than the *P. tuberculatus* Zone

*Haloragacidites harrisii* is abundant and there are lesser amounts of *Myrtacidites* spp and *Nothofagidites* spp. The relative abundances of spores and gymnosperms (see Table 3) are low and there is a rich diversity of low frequency angiosperms.

3). Mid-late Miocene, *T. bellus* Zone, 'Jandra', bore 36853 at 61–63 m

The diagnostic species *Proteacidites symphyonemoides* and *Reticulatisporites cowrensis* first appear in the latest early-mid Miocene *T. bellus* Zone (Stover and Partridge 1973). *Rhoipites ampereaformis*, also present, first appears in the late Miocene-early Pliocene *M. galeatus* Zone (Macphail and Truswell 1993), but only one specimen was found and diagnostic species may occaisionally be found earlier than their accepted first appearance, and it may be a contaminant from the drilling mud. The relatively high abundance of the gymnosperms and *Nothofagus*, especially the *brassopora* species (*N. emarcidus, N. falcatus* and *N. vansteenisii*), are typically that of the *T. bellus* Zone. There are no other features which would definitely indicate the *M. galeatus* Zone, hence this assemblage is assigned to the latest early-mid Miocene *T. bellus* Zone.

4). Late Pliocene-early Pleistocene, Asteraceae-Poaceae phase, Louth, bore 36942 at 20–22 m and 'Jandra', bore 36853 at 21–22 m.

The abundance of *Tubulifloridites* spp with some *Graminidites monoporites* indicates the Asteraceae/Poaceae phase of late Pliocene-early Pleistocene (Martin 1987). *Polyporina granulata* and *Tubulifloridites pleistocenicus* first appear in the late Pliocene-early Pleistocene also.

The two assemblages from bore 36942 lack *T. pleistocenicus*, have lower frequencies of *Graminidites monoporites* and more *Haloragacidites harrissii* than in bore 36853, hence they present a somewhat older aspect than the higher frequencies of *T. pleistocenicus* in bore 36853 that are usually found in younger early Pleistocene assemblages.

In all of these Cainozoic assemblages, no dinoflagellates or any other indication of marine conditions are present. The algae recorded occaisionally (see Table 3) may all be found in fresh water to brackish environments.

## DISCUSSION

Fig. 4 presents a summary of the palynology. In so far as pollen has been recovered, the Tertiary sediments overlying the Early Cretaceous basement are late Eocene at Tilpa and late Oligocene-early Miocene at Louth to 'Jandra'. Mid-late Miocene and late Pliocene-early Pleistocene assemblages are present also, further up the sequence. The Early Cretaceous basement may be either marine or non-marine, but the Tertiary sediments are all fresh water to brackish.
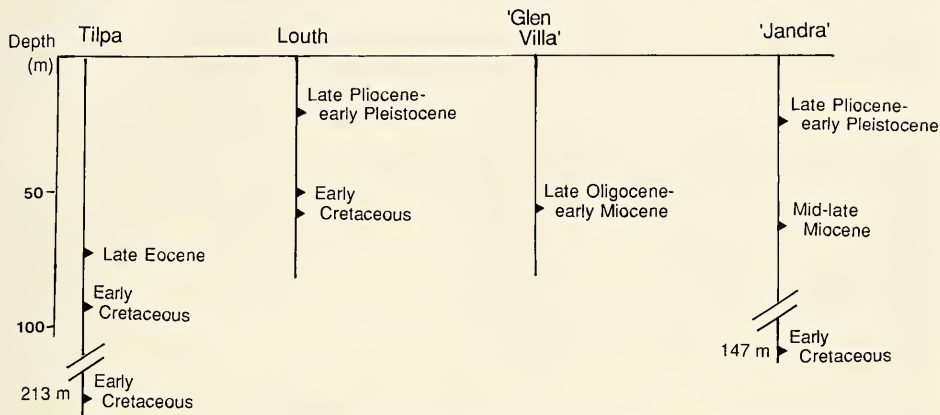


Figure 4. Summary cross section of the bores along the Darling River. For location of bores, see Fig. 1.

TABLE 4

Botanical affinities of the Tertiary spores and pollen.

| Fossil Name | Botanical affinity |
| --- | --- |
| **SPORES** | |
| *Baculatisporites disconformis* | Osmundaceae |
| *Ceratosporites equalis* | *Sellaginella* |
| *Cingulatisporites bifurcatus* | Anthocerotae |
| *Cyatheacidites annulatus* | |
| *Cyathidites* spp | *Cyathea* |
| *Gleicheniidites circinidites* | *Gleichenia* |
| *Polypodiaceoisporites* sp | *Pteris* |
| *Rouseisporites* sp | Hepatic |
| *Todisporites* | Osmundaceae |
| **GYMNOSPERMS** | |
| *Araucariacites australis* | Araucariaceac |
| Cupressaceae | Cupressaceae |
| *Dilwynites granulatus* | Araucariaceae |
| *Lygistepollenites florinii* | *Dacrydium* |
| *Pavisaccites catastus* | *?Dacrydium* |
| *Phyllocladites mawsonii* | *Lagarostrobos franklinii* |
| *P. palaeogenicus* | *Phyllocladus* |
| *Podocarpidites* sp | *Podocarpus sens. lat.* |

## ANGIOSPERMS

| | |
|---|---|
| *Acaciapollenites myriosporites* | *Acacia* |
| *Anacolosidites* spp | *Anacolosa* |
| *Banksieaeidites* spp | Banksieae |
| *Canthiumidites* cf C. *oblatus* | Rubiaceae |
| *Chenopodipollis chenopodiaceoides* | Chenopodiaceae/Amaranthaceae |
| Convolvulaceae (panporate) | Convolvulaceae |
| *Corsinispollinites* | *Ludwidgia* |
| *Cyperaceaepollis* | Cyperaceae |
| *Dodonaea sphaerica* | *Dodonaea* |
| *Fenestrites* | Asteraceae, Liguliflorac |
| *Graminidites media* | Poaceae |
| *Hakea* | *Hakea* |
| *Haloragacidites haloragoides* | *Haloragis* |
| H. *harrisii* | Casuarinaceae |
| *Liliacidites* | ?Liliales |
| Malvaceae | Malvaceae |
| *Malvacearumpollis* — | Malvaceae |
| *Malvacipollis sp* | *Austrobuxus/Dissiliaria* |
| *Montia* | *Montia* |
| *Myriophyllum* | *Myriophyllum* |
| *Myrtaceidites eucalyptoides* | Angophora/bloodwood eucalypt type |
| M. cf M. *eucalyptoides* | Other eucalypts |
| M. *parvus* | *Tristania/Backhousia/Baeckea* |
| M. *verrucosus* | *Archirhodomyrtus/Rhodomyrtus* |
| Myrtaceae unidentified | Myrtaceae |
| *Nothofagidites emarcidus* | *Nothofagus brassii type* |
| N. *falcatus* | *Nothofagus brasssii* type |
| N. *vansteenisii* | *Nothofagus brasssii* type |
| *Nuxipollenites* sp (*Dodonaea triquetra*) | *Dodonaea triquetra* |
| *Perfotricolpites digitatus* | *Merrimia* |
| *Periporopollenites demarcatus* | — |
| P. *vesicus* | — |
| *Potyorificites oblatus* | *Austrobuxus/Dissilaria* |
| *Propylipollis ivanhoensis* | *Helicia/Orites* |
| *Proteacidites rectomarginis* | — |
| P. *reticuloscabratus* | — |
| *Santalumidites cainozoicus* | *?Santalum* |
| *Sapotaceoidaepollenites rotundus* | Sapotaceae |
| *Simplicepollis meridianus* | — |
| *Sparganiaceaepollenites barungensis* | Sparganiaceac |
| S. *sphericus* | Sparganiaceae |
| *Tricolporopollenites endobalteus* | *Macaranga/Mallotus* |
| *Tubulifloridites antipodica/simplis* | Asteraceae |
| T. *pleistocenicus* | Asteraceae |
| Unidentified monosulcates | Monoctyledons, probably some palms |
| Unidentified tricolpate/tricolporates | Dicotyledons |
| Unidentified triporates | Dicotyledons |

Casuarinaceae and to a lesser extent, *Nothofagus* (see Table 4 for botanical affini-
ties) are the predominant pollen types in the late Eocene palynofloras. There is an unusu-
ally low content of the proteaceous pollen type but other rainforest angiosperms, such as
Sapotaceae and *Austrobuxus/Dissiliaria* are well represented. There is a diversity of rain-
forest gymnosperms and under-represented angiosperms. The vegetation was a mixture
of forests, probably mostly Casuarinaceae forests with limited patches of *Nothofagus*
forests and possibly other rainforest types within the catchment. The rainfall was rela-
tively high, above 1,500 mm p.a., the lower limit for rainforest (Martin 1987).

Vegetation in the late Oligocene-Miocene and mid-late Miocene was a mixture of
forest types where Casuarinaceae, *Nothofagus* and gymnosperms were common. The
Glen Villa site probably represents a backswamp where *Ludwidgia* (*Corsinipollinites*)
grew. Previous studies on the Miocene vegetation show that there was considerable vari-
ation (Martin 1990). The rainfall would have been much the same as above.

The late Pliocene-early Pleistocene palynofloras, with their high content of herba-
ceous taxa (Asteraceae, Poaceae, Cyperaceae and Chenopodiaceae) indicate open vegeta-
tion, implying that the forests had disappeared. Casuarinaceae and the eucalypts would
have been the main trees in a sparse cover. The minor quantities of the gymnosperm
Araucariaceae could have come from long distance dispersal or from very minor, relict-
ual stands. The rainfall had decreased considerable, below 1,000 mm, the lower limit for
wet sclerophyll forest (Martin 1987), but it would have been above that of today. A study
of the hydrology of the Plio-Pleistocene megalake, Lake Bungunnia, which extended
over the confluence of the Murray and Darling Rivers, lead Stephenson (1986) to con-
clude that the precipitation of this time was considerably more than at present over the
catchment of the Murray Darling River system.

The algae present (see Table 3) indicate a freshwater to brackish environment
(Pentecost 1984) at the time of deposition, from the late Oligocene to late Pliocene-early
Pleistocene. Today, the water from the Jandra bore has a salinity about that of sea water.
It is likely that the higher rainfall during the late Tertiary would have assisted flushing
salt out of the catchment, but precipitation is not the only factor to be considered. A simi-
lar situation is found in the Tresco bore in northwest Victoria, where groundwater about
twice the salinity of sea water originates from late Pliocene-early Pleistocene sediments
that were deposited under freshwater conditions (Knight and Martin 1989).

The geological structure (Fig. 5) has facilitated the accumulation of highly saline
groundwater. The en echelon arrangement of shallow grabens along the Darling River
Lineament function as 'blind' compartments that inhibit flushing of the aquifers by nor-
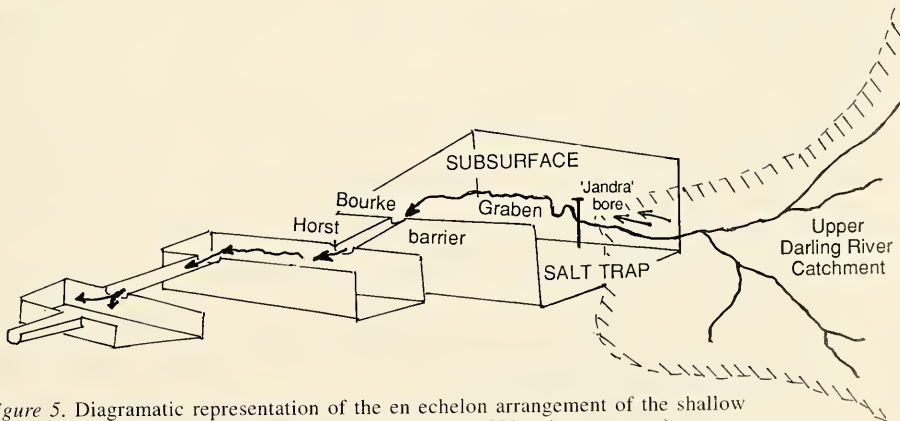


*Figure 5.* Diagramatic representation of the en echelon arrangement of the shallow
grabens that act as traps for saline groundwater (T. Mount 1992 and pers. comm.).

mal downstream movement of groundwater. The bedrock ridges, or horsts, dividing the compartments, have provided effective barriers to groundwater movement, allowing salt to accumulate. The source of the salt can be found in the upper Darling River catchment, above Bourke (from air lofted marine spray, weathered rock and evaporation). The Bourke Graben (T. Mount, pers. comm. and 1992), being the first compartment in the series, is interpreted as the primary trap for the upper catchment salt.

Aridity has increased since the late Pliocene-early Pleistocene, the youngest of the pollen assemblages reported here. During the last 500,000 years, the decreasing rainfall and increasing evaporation, effectively assisted in the build-up of salts (Bowler 1988). The glacial phases of the glacial/interglacial cycles combined low rainfall with strong winds and high evaporation. Freshwater lakes became saline, and if they dried up, the winds spread the salt-laden dust around. When the climate moderated in the interglacial periods, the rainfall increased and the lakes filled with freshwater, but it did not mix well with the saline water which would then recharge the groundwater (Bowler 1988). Though this mechanism may explain much of the salinity problem in inland southeastern Australia today (e.g. the Tresco bore discussed above), the special geological circumstances of the Darling River are probably the major cause of the problems there, but other factors may be involved as well.

## ACKNOWLEDGEMENTS

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